FY2025 Annual Report

Quantum Architecture Unit

Professor Kae Nemoto

Abstract

The Quantum Architecture Unit focuses on the development of theoretical and architectural frameworks for scalable quantum information systems, covering quantum computation, communication, and machine learning. During FY2025, the unit’s activities continued to expand across these areas, with a particular emphasis on understanding how physical resources—such as coherence, loss, and entanglement generation—translate into system-level performance.

A number of results this year reflect this direction. These include improved continuous-variable quantum repeater protocols with significantly enhanced key rates, the introduction of new entanglement measures that capture characteristic length scales in quantum networks, and the development of routing models that incorporate quality-of-service considerations in distributed quantum systems. In parallel, work on quantum machine learning explored hardware-efficient approaches based on simple Hamiltonian dynamics and reservoir computing, demonstrating practical performance even in relatively small systems.

Taken together, these efforts contribute to a more unified view of quantum system design, linking device-level constraints to architectural performance. The work is closely aligned with several national initiatives, including Moonshot, Q-LEAP, COI-NEXT, SIP, and NEDO, and supports ongoing efforts toward the realisation of scalable quantum technologies.

1. Staff

- Kae Nemoto, Professor
- Nicolo Lo Piparo, Staff Scientist
- Akitada Sakurai, Senior Project Scientist
- Hon Wai Lau, Postdoctoral Scholar
- Nicholas Connolly, Postdoctoral Scholar
- Yuwei Zhu, Postdoctoral Scholar
- Ananga Datta, Postdoctoral Scholar
- Chaimae El Bouazizi, Technician
- Aoi Hayashi, Special Research Student

PhD students
Thesis Supervising

- Sougato Chowdhury

Co-Supervising

- Tatiana Iakovleva
- Ilia Ryzov

Mentoring
- Aswathy Raj
- Amal Jose

Third Committee Member
- Snigdh Sabharwal
- Sarika Sasidharan Nair

Lab Rotation Supervising
- Hideaki Kawai
- Biswaranjan Panda
- Syoub Hamza Rhim

Visiting Research Student
- Jhao Ting Lin
- Sanino Da Silva, Marina Heloysa

2. Collaborations

2.1 Architecture and applications for small to large scale quantum computation [MEXT, Quantum Leap Flagship Program] (Principal Investigator: Kae Nemoto)

- Type of collaboration: Joint project
- Researchers:
  - Prof. Mio Murao, University of Tokyo
  - Prof. Takeaki Uno, National Institute of Informatics

2.2 Large-scale distributed quantum computer architecture [JSPS, Grant-in-Aid for Scientific Research(A)] (Principal Investigator: Kae Nemoto)

- Type of collaboration: Joint research
- Researchers:
  - Prof. William J. Munro, OIST

2.3 Research and Development of Theory and Software for Fault-tolerant Quantum Computers [Cabinet Office, Moonshot Research and Development Program] (Project Manager: Masato Koashi)

- Type of collaboration: Joint project
- Researchers:
  - Prof. William J. Munro, OIST
  - Dr. Peizhe Li, OIST

2.4 Scalable and Robust Integrated Quantum Communication System [Cabinet Office, Moonshot Research and Development Program] (Project Manager: Shota Nagayama)

- Type of collaboration: Joint project
- Researchers:
  - Dr. Nicholas Connolly, OIST
  - Dr. Ananga Datta, OIST

2.5 Center of Innovation for Sustainable Quantum AI [JST, Program on Open Innovation Platforms for Industry-academia Co-creation (COI-NEXT)] (Project Leader: Shinji Todo)

- Type of collaboration: Joint project
- Researchers:
    - Prof. Thomas Busch, OIST
    - Dr. Thomás Fogarty, OIST
    - Dr. Yuwei Zhu, OIST
    - Chaimae El Bouazizi, Technician, OIST

2.6 Promoting the application of advanced quantum technology platforms to social issues [The Cross-ministerial Strategic Innovation Promotion Program（SIP）, Promoting the application of advanced quantum technology platforms to social issues] (Principal Investigator: Kae Nemoto)

- Type of collaboration: Joint project (See OCQT website)

2.7 Development of Human Resources for Non-Hardware Development in Quantum Computing [Research and Development Project of the Enhanced Infrastructures for Post-5G Information and Communication Systems (NEDO)] (Principal Investigator: Kae Nemoto)

- Type of collaboration: Joint project

2.8 Quantum reservoir computing [Collaborative research with DENSO Corporation] (Principal Investigator: Kae Nemoto)

- Type of collaboration: Joint research

2.9 Research on 1st generation quantum repeater with quantum memory [Collaborative research with Toshiba Corporation] (Principal Investigator: Kae Nemoto)

- Type of collaboration: Joint research

3. Activities and Findings

The research activities in FY2025 span several interconnected directions, broadly covering quantum networks and communication, quantum machine learning, and open quantum systems. While these areas are quite diverse, a common thread is the focus on how system behaviour emerges from underlying physical constraints, and how this can be used to guide the design of scalable quantum architectures.

3.1 Continuous-variable multiplexed quantum repeater networks

Continuous-variable (CV) codes and their application in quantum communication have attracted increasing attention. In particular, one typical CV codes, cat-codes, has already been experimentally created using trapped atoms in cavities with relatively high fidelities. However, when these codes are used in a repeater protocol, the secret key rate

(SKR) that can be extracted between two remote users is extremely low. Here we propose a quantum repeater protocol based on cat codes with a few quantum memories or graph states as additional resources. This allows us to considerably increase the SKR by several orders of magnitude. Our findings provide valuable insights for designing efficient quantum repeater systems, advancing the feasibility and performance of quantum communication over long distances.

3.2 Nonconvex entanglement monotone determining the characteristic length of entanglement distribution in continuous-variable quantum networks

Quantum networks (QNs) promise to enhance the performance of various quantum technologies in the near future by distributing entangled states over long distances. The first step towards this is to develop novel entanglement measures that are both informative and computationally tractable at large scales. While numerous such entanglement measures exist for discrete-variable (DV) systems, a comprehensive exploration for experimentally preferred continuous-variable (CV) systems is lacking. Here, we introduce a class of CV entanglement measures, among which we identify a nonconvex entanglement monotone—the ratio negativity, which possesses a simple, scalable form that determines the exponential decay of optimal entanglement swapping on a chain of pure Gaussian states. This characterization opens avenues for leveraging statistical physics tools to analyze swapping-protocol-based CV QNs.

3.3 Simple Hamiltonian dynamics as a powerful resource for image classification

A quadrillion-dimensional Hilbert space hosted by a quantum processor with over 50 physical qubits has been expected to be powerful enough to perform computational tasks ranging from simulations of many-body physics to complex financial modeling. Despite a few examples and demonstrations, it is still unclear how we can utilize such a large Hilbert space as a computational resource, particularly how a simple and small quantum system could solve nontrivial computational tasks. This paper shows a simple Ising model capable of performing such nontrivial computational tasks in a quantum neural network model. An Ising spin chain as small as ten qubits can solve a practical image classification task with high accuracy. To evaluate the mechanism of its computation, we examine how the symmetries of the Hamiltonian would affect its computational power. We show how the interplay between complexity and symmetries of the quantum system dictates the performance as quantum neural network.

3.4 Quantum optical reservoir computing powered by boson sampling

It is well known that boson sampling, a restricted non-universal quantum computation model, enables one to perform tasks that are hard to accomplish with digital computers. Boson sampling is associated with sampling the probability distribution of identical bosons passing through a random interferometer, and its quantum advantage has been demonstrated. It has, however, proven elusive to use such a model for practical applications. In this work, we show that the random interferometer powering boson sampling can be used to generate the complex dynamics necessary for quantum reservoir computing. We use these dynamics to perform various image recognition problems, illustrating the utility of the approach even for modest-size systems.

3.5 Quality of service in aggregated quantum networks

Future quantum networks will enable the interconnection of multiple users distributed across vast geographic distances. Due to these large separations and limited physical resources, communication will often rely on multipath routing strategies, where physical resources are distributed across channels of varying lengths and delivered to end users. Efficient long-distance quantum communication therefore requires optimizing the allocation of these resources across available paths. In this work we introduce a performance-oriented approach to quantum network routing by extending the classical concept of quality of service (QOS) to the context of multipath quantum resource distribution. Unlike prior models that consider entanglement generation or quantum memory coherence in isolation, we investigate the interplay between path assignment strategies, coherence time constraints, and quantum error correction (QEC) and how they jointly impact end-to-end communication fidelity. We analyze both unencoded and encoded transmissions over aggregated network paths, quantifying the effects of resource allocation on transmission success. Our findings show that fidelity cannot be optimized independently of memory lifetimes and that while QEC can enhance performance under specific conditions, it also imposes additional constraints depending on network topology and path-length asymmetries. This work provides a foundation for developing QOS-aware quantum routing protocols that balance fidelity, throughput, and memory utilization, key considerations for near-term quantum repeater networks.

3.6 Quantum phase transitions in the multiphoton Jaynes-Cummings-Hubbard model

We explore quantum phase transitions in the multiphoton Jaynes-Cummings-Hubbard model (JCHM). Using the mean-field approximation, we demonstrate that the multiphoton JCHM exhibits quantum phase transitions between the Mott insulator (MI) phase, the superfluid phase, and an additional phase we refer to as the forbidden phase. The multiphoton JCHM MI phases are classified according to a conserved quantity associated with the total number of excited atoms and photons. When this conserved quantity diverges toward positive infinity, this system enters the forbidden phase. By analyzing the system, we observe MI, superfluid, and forbidden phases in both the single- and two-photon JCHMs, although the MI phases in the two-photon case are confined to subspaces with small values of the conserved quantity. In contrast, only the superfluid and forbidden phases appear in the three- and four-photon JCHMs, with no MI phase observed.

3.7 Equilibration of noninteracting photons and quantum signatures of chaos

Equilibration plays a fundamental role in our understanding of statistical mechanics and the long-time dynamics of many-body systems. In quantum systems, the route to equilibration is intimately related to level repulsion and quantum signatures of chaos that are encoded in their unitary evolution. Chaotic quantum systems exhibit level statistics characteristic of ensembles of random matrices. In this work, we demonstrate that single-particle chaos leads to equilibration of many noninteracting photons. We show that the underlying mechanisms for equilibration are operator spreading and quantum interference. More specifically, we demonstrate that the unitary dynamics of a general Floquet system implemented using single-mode phase shifters and multiport beamsplitters leads to equilibration of photons. We propose a realistic photonic implementation of the multiparticle kicked rotor, which is a Floquet system that we use as a concrete example of our general approach.

3.8 Women for quantum—manifesto of values

Data show that the presence of women in quantum science is affected by a number of detriments and their percentage decreases even further for higher positions. Beyond data, from our shared personal experiences as female tenured quantum physics professors, we believe that the current model of scientific leadership, funding, and authority fails to represent many of us. Women for quantum calls for a joint effort and aims with this initiative to contribute to such a transformation. It is time for a real change that calls for a different kind of force and for the participation of everyone.

3.9 Fault-tolerant quantum computation without distillation on a 2D device

We show how looped pipeline architectures—which use short-range shuttling of physical qubits to achieve bounded non-local connectivity—can efficiently implement the fault-tolerant non-Clifford gate between 2D surface codes described in (Sci. Adv. 6, eaay4929 (2020)). The shuttling schedule required is only marginally more complex than is required for implementing the standard 2D surface code in this architecture. We compare the resource cost with the cost of magic state distillation and find that, at present, this comparison is heavily in favour of distillation. The high cost of the non-Clifford gate is largely due to the relatively low performance of the just-in-time decoder used in the procedure, which necessitates very large code distances in order to achieve suitably low logical error rates. We argue that, as little attention has been given to the study and optimisation of these decoders, there are potentially significant improvements to be made in this area.

3.10 Quantum Communication Networks Enhanced by Distributed Quantum Memories

Building large-scale quantum communication networks has its unique challenges. Here, we demonstrate that a network-wide synergistic usage of quantum memories distributed in a quantum communication network offers a fundamental advantage. We first map the problem of quantum communication with local usage of memories into a classical continuum percolation model. Then, we show that this mapping can be improved through a cooperation of quantum distillation and relay protocols via remote access to distributed memories. This improved mapping, which we term $¥alpha$-percolation, can be formulated in terms of graph-merging rules, analogous to the decimation rules of the renormalization group treatment of disordered quantum magnets. These rules can be performed in any order, yielding the same optimal result that is characterized by the emergence of a “positive feedback" mechanism and the formation of spatially disconnected “hopping" communication components – both marking significant improvements beyond the traditional point-to-point consideration of quantum communication in networked structures.

3.11 Self-induced superradiant masing

In cavity quantum electrodynamics and particularly superradiance, emitters are typically assumed to be independent, interacting only through light shared via a common mode. Although such photon-mediated interactions lead to a wide range of collective optical effects, direct dipole–dipole interactions within the emitter ensemble are generally viewed as a source of decoherence. Here we report the role of direct spin–spin interactions as a drive for the superradiant dynamics of a hybrid system of nitrogen-vacancy centre spins in a diamond coupled to a superconducting microwave cavity. After an initial fast superradiant burst, we observe a train of subsequent emission pulses followed by quasi-continuous masing for up to one millisecond. We show that this behaviour arises from spectral hole refilling, where spin inversion is redistributed into the superradiant window of spins resonant with the cavity. We report measurements that exclude other cavity-related effects and perform microscopic simulations that confirm that the observed behaviour is driven by dipole–dipole interactions between the spins. These findings open pathways for exploring complex spin–spin interactions in dense disordered systems and offer possibilities for ultranarrow-linewidth solid-state superradiant masers powered purely by microwave-driven spin control.

3.12 Efficient charging of multiple open quantum batteries through dissipation and pumping

We explore a protocol that efficiently charges multiple open quantum batteries in parallel using a single charger. This protocol charges through collective coupling of the charger and the battery to the same thermal reservoir. When applied to multiple quantum batteries, each coupled to different thermal reservoirs, the energy cannot be efficiently transferred from the charger to the battery via collective dissipation alone. We show that the counterintuitive act of incorporating both dissipation and incoherent collective pumping on the charger enables efficient parallel charging of many quantum batteries.

3.13 Modular quantum extreme reservoir computing

Quantum reservoir computing employs fixed quantum dynamics as a feature map for machine learning. Integrating multiple quantum reservoirs, however, raises a key question: how few intermodule connections are sufficient to match the performance of a single reservoir? To address this, we explicitly separate intramodule dynamics from intermodule couplings and systematically examine different connectivity schemes. We find that even a small number of well-placed connections between two modules can match single-reservoir accuracy, with simple one-to-one connections proving highly effective. Performance generally improves with increasing intermodule entanglement, and these correlations persist for both ZZ-coupled and random modular reservoirs. Extensions to three modules and evaluations across multiple datasets (MNIST, Fashion-MNIST, CIFAR-10) suggest that the modular architecture can be applied to diverse reservoir types and image-classification datasets. These results motivate modular quantum reservoir designs that align naturally with realistic hardware, such as two-dimensional quantum-chip layouts or networks of small integrated quantum systems.

3.14 Loophole-free Bell-inequality violation between atomic states in cavity-QED systems mediated by hybrid atom–light entanglement

We present a feasible approach to testing Bell nonlocality and implementing device-independent quantum key distribution (DI) between distant atomic states in cavity-based architectures, mediated by hybrid atom–light entanglement. We develop a full theoretical model that incorporates realistic sources of noise—such as transmission loss, limited light–matter coupling efficiency, and imperfect detection. Our analysis shows that strong Bell–Clauser–Horne–Shimony–Holt violations and secure key generation over tens of kilometers are within reach using current or near-term technology. These results position cavity-based platforms with coherent-state encodings as a promising foundation for future DI quantum communication networks.

4. Publications

4.1 Journals

1. Pei-Zhe Li, William J. Munro, Kae Nemoto, Nicolò Lo Piparo, *Continuous-variable multiplexed quantum repeater networks*, Quantum Science and Technology 10, 025057, https://doi.org/10.1088/2058-9565/adc500 (2025)
2. Yaqi Zhao, Jinchuan Hou, Kan He, Nicolò Lo Piparo and Xiangyi Meng, *Nonconvex entanglement monotone determining the characteristic length of entanglement distribution in continuous-variable quantum networks*, Physical Review A 111, 042429, https://doi.org/10.1103/PhysRevA.111.042429 (2025)

3. Akitada Sakurai, Aoi Hayashi, W. J. Munro, Kae Nemoto, *Simple Hamiltonian dynamics as a powerful resource for image classification*, Physical Review A 111, 052432, https://doi.org/10.1103/PhysRevA.111.052432 (2025)
4. Akitada Sakurai, Aoi Hayashi, William J. Munro, Kae Nemoto, *Quantum optical reservoir computing powered by boson sampling*, Optica Quantum 3(3), 238–245, https://doi.org/10.1364/OPTICAQ.541432 (2025)
5. Nicolò Lo Piparo, William J. Munro, Kae Nemoto, *Quality of service in aggregated quantum networks*, Physical Review A 112, 022611, https://doi.org/10.1103/ph6d-qqwk (2025)
6. Hiroo Azuma, William J. Munro, Kae Nemoto, *Quantum phase transitions in the multiphoton Jaynes-Cummings-Hubbard model*, Physical Review A 112(3), 033709, https://doi.org/10.1103/ypts-6z4p (2025)
7. V. M. Bastidas, H. L. Nourse, A. Sakurai, A. Hayashi, S. Nishio, Kae Nemoto, W. J. Munro, *Equilibration of noninteracting photons and quantum signatures of chaos*, Physical Review B 112, 134304, https://doi.org/10.1103/tmw1-vry7 (2025)
8. Almut Beige, Ana Predojević, Anja Metelmann, Anna Sanpera, Chiara Macchiavello, Christiane P. Koch, Christine Silberhorn, Costanza Toninelli, Dagmar Bruß, Elisa Ercolessi, Elisabetta Paladino, Francesca Ferlaino, Giulia Ferrini, Gloria Platero, Ivette Fuentes, Kae Nemoto, Leticia Tarruell, Maria Bondani, Marilu Chiofalo, Marisa Pons, Milena D'Angelo, Mio Murao, Nicole Fabbri, Paola Verrucchi, Pascale Senellart-Mardon, Roberta Citro, Roberta Zambrini, Rosario González-Férez, Sabrina Maniscalco, Susana Huelga, Tanja Mehlstäubler, Valentina Parigi, Verónica Ahufinger, *Women for Quantum - Manifesto of Values*, Communications Physics 8, 422, https://doi.org/10.1038/s42005-025-02321-9 (2025)
9. Thomas R. Scruby, Kae Nemoto, Zhenyu Cai, *Fault-tolerant quantum computation without distillation on a 2D device*, npj Quantum Information 11, 189, https://doi.org/10.1038/s41534-025-01133-7 (2025)
10. Xiangyi Meng, Nicolò Lo Piparo, Kae Nemoto, and István A. Kovács, *Quantum Communication Networks Enhanced by Distributed Quantum Memories,* Quantum 9, 1948 https://doi.org/10.22331/q-2025-12-15-1948 (2025)
11. Wenzel Kersten, Nikolaus de Zordo, Oliver Diekmann, Elena S. Redchenko, Andrew N. Kanagin, Andreas Angerer, William J. Munro, Kae Nemoto, Igor E. Mazets, Stefan Rotter, Thomas Pohl, Jörg Schmiedmayer, *Self-induced superradiant masing*, Nature Physics 22, 158–163, https://doi.org/10.1038/s41567-025-03123-0 (2026)
12. Josephine Dias, Hui Wang, Kae Nemoto, Franco Nori, and William J. Munro, *Efficient charging of multiple open quantum batteries through dissipation and pumping*, Phys. Rev. A 113, 012617, https://doi.org/10.1103/jy9l-l8hv (2026)
13. Hon Wai Lau, Aoi Hayashi, Akitada Sakurai, William John Munro, Kae Nemoto, *Modular quantum extreme reservoir computing*, Phys. Rev. A 113, 012429, https://doi.org/10.1103/111d-yxg8 (2026)
14. Pei-Zhe Li, Soumyakanti Bose, Hyunseok Jeong, William J Munro, Kae Nemoto and Nicolò Lo Piparo, *Loophole-free Bell-inequality violation between atomic states in cavity-QED systems mediated by hybrid atom–light entanglement*, Quantum Sci. Technol. 11, 025027

https://doi.org/10.1088/2058-9565/ae5089 (2026)

4.2 Proceedings

1. William J. Munro, Akitada Sakurai, Aoi Hayashi, Hon Wai Lau, Kae Nemoto, *Image recognition powered by photonic reservoir computation*, Proceedings of Optica Quantum 2.0 Conference and Exhibition, Technical Digest Series (Optica Publishing Group), paper QTu4A.5, https://opg.optica.org/ViewMedia.cfm?uri=QUANTUM-2025-QTu4A.5&seq=0 (2025)
2. Nicolo Lo Piparo, William J. Munro, Kae Nemoto, *Routing for an aggregated quantum network*, IEEE INFOCOM 2025 – IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), https://10.1109/INFOCOMWKSHPS65812.2025.11153012 (2025)
3. Kae Nemoto, Akitada Sakurai, Aoi Hayashi, William J. Munro, *Information processing through lossy optical quantum networks*, Proceedings of SPIE PC13618, Quantum Communications and Quantum Imaging XXIII, PC1361809, https://doi.org/10.1117/12.3062973 (2025)

4.3 Oral and Poster Presentations

Invited Oral Presentation

1. Kae Nemoto, *Communication for Computation*, Nordita Fault-Tolerant Quantum Computing Workshop: From Theory to Practice, Albano Campus, Nordita, Stockholm, Sweden (2025/7/3)
2. Kae Nemoto, *Information processing through lossy optical quantum networks*, Quantum Communications and Quantum Imaging XXIII, San Diego, USA (2025/8/3)
3. Kae Nemoto, *Questions That Are Not Meant to Be Answered*, Global Young Scientists Summit 2026, the National Research Foundation Singapore (NRF), Singapore (2026/1/7) (Plenary talk)
4. Kae Nemoto, *Photonic Architecture for Quantum Machine learning,* W4Q: Quantum Science Conference, Palma de Mallorca, Spain (2026/3/25)

Invited Oral Presentation for Members

1. Nicolo Lo Piraro *Routing for an aggregated quantum network* IEEE International Conference on Computer Communications, London, UK（IEEE INFOCOM 2025）, (2025/5/19)
2. Nicholas Connolly, *A Brief Overview of some Quantum Erasure Decoding Algorithms*, Quantum Error Correction Theory Workshop for Young Researchers, Nagoya, Japan (2025/12/19)

Oral Presentation for members

1. Nicolò Lo Piparo, *A continuous variable quantum repeater protocol based on cavity-QED*, ICSM-ICQMT 2025 (10th International Conference on Superconductivity and Magnetism / 3rd International Conference on Quantum Materials and Technologies), Turkey (2025/4/30)
2. Nicolò Lo Piparo, *Routing for aggregated quantum networks*, 111th Congresso Nazionale (Italian Physical Society), Palermo, Italy (2025/9/25)
3. Akitada Sakurai, *An efficient approach to realize Quantum Random Features*, 9th international conference on quantum techniques in machine learning (QTML2025), National University of Singapore, Marina Bay Sands Singapore, Singapore (2025/11/21)
4. Akitada Sakurai, *Physical Resource-Efficient Feature Maps via Quantum Random Features*, Biological, Artificial, and Quantum Intelligence 2026 (BAQ2026) International workshop, The Moon Beach Museum Resort, Okinawa (2026/3/3）

5. Aoi Hayashi, *Impact of network properties of quantum dynamics on generalization performance in quantum extreme reservoir computation*, Biological, Artificial, and Quantum Intelligence 2026 (BAQ2026) International workshop, The Moon Beach Museum Resort, Okinawa (2026/3/4）
6. Sougato Chowdhury, *Using Quantum Cellular Automata for Machine Learning*, Biological, Artificial, and Quantum Intelligence 2026 (BAQ2026) International workshop, The Moon Beach Museum Resort, Okinawa (2026/3/4）

Poster Presentations for members

1. Nicholas Connolly, *Exploring Graph State Local Equivalence Classes with Distance Hereditary Split Decompositions,* Quantum Innovation 2025, Osaka (2025/7/29)
2. Hon Wai Lau, *Quantum Memory Resource Advantage in Reinforcement Learning*, 9th international conference on quantum techniques in machine learning (QTML2025), Singapore (2025/11/18)
3. Aoi Hayashi, *Information-theoretic evaluation of quantum machine learning model complexity*,9th international conference on quantum techniques in machine learning (QTML2025) Singapore, (2025/11/18)
4. Nicholas Connolly, *Exploring Graph State Local Equivalence Classes with Distance Hereditary Split Decompositions*, the first is a poster presentation at the JAIST International Symposium on Quantum Research in Kanazawa, Kanazawa (2025/11/28)
5. Akitada Sakurai, *New quantum machine learning models: Quantum Random and Dynamical Random Features*, W4Q Quantum Science conference, Palma de Mallorca, Spain (2026/3/23)

Other Invited Lectures

1. 根本 香絵, *量子情報科学技術の最先端研究から新しい潮流を生み出す*, 沖縄科学技術大学院大学発展促進県民会議, OIST 講堂（2025/8/13）
2. 根本 香絵,*産学連携による量子人材育成プログラムの開発と実践*, SIP-BRIDGE シンポジウム, イイノホール&カンファレンスセンター, 東京（2025/10/3）
3. 根本 香絵, *Quantum Computer Architecture from FTQC to Near-Future Quantum Processors*, RCS コロキウム, 理化学研究所, 和光, 埼玉（2025/11/7）
4. 根本 香絵, *「量子未来社会の健全な発展へ向けた課題と展望」について*, 日本学術会議 第 19 回情報学シンポジウムー量子未来社会の健全な発展へ向けた課題と展望ー, 日本学術会議講堂（六本木）（2026/1/14）
5. 根本 香絵, , *量子技術の社会実装に向けた最新動向*, JAXA 内勉強会, JAXA 東京事務所（御茶ノ水）（2026/1/16）
6. 根本 香絵, *Research and Development Approaches that Leverage Diversity*, Japan CTO Forum, OIST 講堂（2026/1/27）
7. 根本 香絵, *量子技術の産業化と人材育成-産官学の連携促進-*, Q-STAR エグゼクティブセミナー 人材育成特別セッション「人材育成特別セッション「量子時代の人材戦略と競争力」～産業化・社会実装の加速に向けた人材像と企業の役割～, 日本橋三井ホール, 日本橋（2026/2/5）
8. 根本 香絵, *量子技術分野における人材育成の特性と課題*, 量子人材育成シンポジウム—現在地と展望ー, 文部科学省・量子研究推進室, 法政大学ボアソナード・タワー（2026/3/11）

Other publications

1. 根本 香絵, *これからの社会を切り拓く戦略的技術分野の最新トレンド*, 視点 号外版, JAXA 調査国際部 (2025/3)

Press release

1. *Boson sampling finds first practical applications in quantum AI,* OIST Center for Quantum Technologies (OCQT), OIST Press Release (2025/6/25)
2. *研究成果と教育体制を報告　OIST　科学・産業の未来図描く*, OIST Center for Quantum Technologies (OCQT), 宮古新報 (2025/8/14)
3. *沖縄振興目指しOISTを支援,* OIST Center for Quantum Technologies (OCQT), 沖縄タイムス (2025/8/15)

5. Honors and Awards

1. 根本 香絵, *量子コンピュータアーキテクチャ理論の研究*, 科学技術分野の文部科学大臣表彰 科学技術賞, 文部科学省 (2025/4/8)
2. 西尾 真, *Online Job Scheduler for Fault-tolerant Quantum Multiprogramming,* 第14回量子ソフトウェア研究会　学生奨励賞（QS研究会），情報処理学会(2025/6/26)

6. Intellectual Property Rights and Other Specific Achievements

Nothing to report

7. Meetings and Events

7.1 Symposiums and Workshops

7.1.1 Okinawa School in Physics: From quantum key distribution to the quantum internet (OSP2025)

- Date: September 21- October 3, 2025
- Venue: OIST Seaside House
- Organizer:

  Artur Ekert, Okinawa Institute of Science and Technology Graduate University (OIST)
  David Elkouss, Okinawa Institute of Science and Technology Graduate University (OIST)
  Kae Nemoto, Okinawa Institute of Science and Technology Graduate University (OIST)
- Workshop URL:

  https://www.oist.jp/conference/osp2025#toc18

7.1.2 2nd International Workshop on Quantum Information Engineering (QIE2025)

- Date: October 8-10, 2025
- Venue: OIST Seaside House
- Organizer: Quantum Information Engineering Professional Group, the Japan Society of Applied Physics (JSAP)
- Co-organizer:

  Okinawa Institute of Science and Technology (OIST)
  Quantum Information Research Center (QIC), Yokohama National University
  Quantum Electronics Professional Group, the Japan Society of Applied Physics (JSAP)
  Moonshot Research and Development Program Goal 6, Japan Science and Technology Agency
- Workshop URL:

  https://annex.jsap.or.jp/qie/QIE2025/index.html

7.1.3 Biological, Artificial, and Quantum Intelligence 2026 International Workshop（BAQ2026）

- Date: March 3-5, 2026
- Venue: The Moon Beach Museum Resort, Onna, Okinawa, Japan
- Organizer:
  Kae Nemoto, Quantum Architecture Unit, OIST
  William Munro, Quantum Engineering and Design Unit, OIST
  Gerald Pao, Biological Nonlinear Dynamics Data Science Unit, OIST
- Workshop URL:
  https://www.oist.jp/conference/baq2026

7.2 Seminars and Events

Activities at OCQT

Seminars

7.2.1 Architectures and Algorithms for Early FTQC (OCQT seminar)

- Date: May 15, 2025
- Venue: OIST Campus
- Speaker: Dr. Andreas M. D. Thomasen (QunaSys)

7.2.2 On the application of quantum-centric supercomputing for electronic structure problems (OCQT seminar)

- Date: August 15, 2025
- Venue: OIST Campus
- Speaker: Dr. Javier Robledo Moreno (IBM Quantum)

7.2.3 Using interference in Pauli space to measure beyond-classical local out-of-time-order correlator (OCQT seminar)

- Date: September 22, 2025
- Venue: OIST Campus
- Speaker: Dr. Nikita Astrakhantsev (Google Quantum AI)

7.2.4 The quantum communication power of indefinite causal order (OCQT seminar)

- Date: December 5, 2025,
- Venue: OIST Campus
- Speaker: Prof. Giulio Chiribella (The University of Hong Kong)

7.2.5 Quantum Measurements at Particle Colliders and Their Applications to New-Physics Searches (OCQT seminar)

- Date: December 15, 2025,
- Venue: OIST Campus

- Speaker: Prof. Kazuki Sakurai (University of Warsaw, Poland)

Events

7.2.6 Commemorative Event for the Signing of the MoU (Memorandum of Understanding – Collaboration Agreement) between AIST and OIST

- Date: April 14, 2025
- Venue: OIST Campus
- https://groups.oist.jp/ocqt/event/world-quantum-day-commemorative-event-co-hosted-oist-and-aist

7.2.7 Research & Career Seminar, co-hosted by the OIST Center for Quantum Technologies (OCQT) and the National Institute of Advanced Industrial Science and Technology (AIST)

- Date: August 26, 2025
- Venue: OIST Campus
- https://groups.oist.jp/ocqt/event/research-career-seminar-aist

7.2.8 Science Day Gunma 2025 –The World of Quantum Mechanics

- Date: October 28, 2025
- Venue: Gunma University, Aramaki Campus University Hall
- Organizers: Gunma University & OIST Center for Quantum Technologies
- https://groups.oist.jp/ocqt/event/science-day-gunma-2025-%E2%80%93-world-quantum-mechanics%E2%80%93

Activities at Unit

7.2.9 Quantum photonics with vanadium in 4H-SiC (Unit seminar)

- Date: January 28, 2026
- Venue: OIST Campus
- Dr. Thomas Astner (IQOQ, Austrian Academy of Sciences)

7.2.10 Online Systems for Fault-tolerant Quantum Computing (Unit seminar)

- Date: February 24, 2026
- Venue: OIST Campus
- Prof. Shin Nishio (Keio University)

8. OIST committees and External Services

OIST committees

1. Tenure Review Evaluation Committee (2025.7-2025.10)

External Services

Duties as QIH

2. Quantum Innovation 2025 (The international symposium on Quantum Science, Technology and Innovation), Committee members (2025.4-2026.3)
3. Quantum Innovation Hub, Human Resource Development Committee, Chair
4. Quantum Innovation Hub, Management Council, member

Academic services

5. Science of Council of Japan, Associate Collaborative Member of Science Council of Japan (2022.4-2026.9)
6. Quantum ICT Forum, Deputy Representative Director (2022.4-2025.6)
7. Information Processing Society of Japan, SIG Quantum Software (SIGQS), Coordinators (2022.4-2026.3)
8. 2nd International Workshop on Quantum Information Engineering (QIE2025), Organizing Committee (2025)
9. Photonics division, The Japan Society of Applied Physics, Program Coordinators（Workshops）, (2025.4-2027.3)

Governmental services

10. Japan Science and Technology Agency, Center for Research and Development Strategy (JST-CRDS), Specialty Committee member (2022.9-2026.3)
11. Ministry of Education, Culture, Sports, Science and Technology (MEXT), NISTEP, Experts investigator (2024.4-2026.3)

Institute/Grant/Project/Award evaluation

12. Japan Science and Technology Agency (JST) , PRESTO(SAKIGAKE Grant) Research area advisor (2022.4-2026.3)
13. Quantum Engineering Programme, Singapore Panel member (2023.2-2026.2)
14. Japan Society for the Promotion of Science (JSPS), World Premier International Research Center Initiative (WPI), Program Committee member (2023.4-2028.3)
15. Wellinq Ltd., Paris, Scientific Committee Member (2023.10-2038.1)
16. MITSUI & CO. LTD., Advisor (2024.10-2026.9)
17. SkillupNeXt, Reviewer of the documents (2025.7-2026.2)
18. International Center for Elementary Particle Physics, the University of Tokyo , Evaluation Committee Member of ICEPP (2025.1)

Position in other universities

19. National Institute of Informatics, Principles of Informatics Research Division, Project professor (2022.4-2026.3) to manage two Q-LEAP projects (one of them is shared with OIST)

9. Others

Professional membership

1. Institute of Physics (UK)
2. American Physical Society (USA)
3. OPTICA (USA)
4. 日本物理学会
5. 応用物理学会

6. 情報処理学会
7. 電子情報通信学会

Collaborations

1. Jörg Schmiedmayer (Technische Universität Wien (TU-Wien) Austria) and Wenzel Kersten et. al (Vienna Center for Quantum Science and Technology, Austria), Self-induced superradiant masing
2. Michael Trupke (Austrian Academy of Sciences, Austria), Architecture and applications for small to large scale quantum computation
3. Zhenyu Cai (University of Oxford, UK), Fault-tolerant quantum computation without distillation on a 2D device
4. Xiangyi Meng (Rensselaer PolytechnicInstitute, USA) and István A. Kovács (Northwestern University, USA), Quantum communication networks enhanced by distributed quantum memories
5. Hui Wang and Franco Nori (RIKEN, Japan), Efficient charging of multiple open quantum batteries through dissipation and pumping

External Grants

1. Ministry of Education, Culture, Sports, Science and Technology (MEXT), MEXT - Quantum Leap Flagship Program (MEXT Q-LEAP), Architecture and applications for small to large scale quantum computation (2018-2027) Principal Investigator
2. The Japan Society for the Promotion of Science (JSPS), Grant-in-Aid for Scientific Research(A) , Large-scale distributed quantum computer architecture (2021-2025) , Principal Investigator
3. Cabinet Office, Government of Japan, Moonshot Research and Development Program (Project Manager: Masato Koashi) Research and Development of Theory and Software for Fault-tolerant Quantum Computers (2021-2025), Co-Investigator
4. Cabinet Office, Government of Japan, Moonshot Research and Development Program (Project Manager: Shota Nagayama), Scalable and Robust Integrated Quantum Communication System (2022-2025), Co-Investigator
5. Japan Science and Technology Agency(JST), Program on Open Innovation Platforms for Industry-academia Co-creation (COI-NEXT), (Project Leader: Shinji Todo) Center of Innovation for Sustainable Quantum AI (2022-2031), Co-Investigator
6. Cabinet Office, Government of Japan, The Cross-ministerial Strategic Innovation Promotion Program（SIP）, Promoting the application of advanced quantum technology platforms to social issues(2023-2027), Principal Investigator
7. New Energy and Industrial Technology Development Organization（NEDO）, Research and Development Project of the Enhanced Infrastructures for Post-5G Information and Communication Systems, Development of Human Resources for Non-Hardware Development in Quantum Computing (2025-2027), Principal Investigator
8. Collaborative research, DENSO Corporation, Quantum reservoir computing (2023-2025), Principal Investigator
9. Collaborative research, Toshiba Corporation, Research on 1st generation quantum repeater with quantum memory (2024-2025), Principal Investigator

External Grants for Unit members

1. Nicolo Lo Piparo: The Japan Society for the Promotion of Science (JSPS), Grant-in-Aid for Scientific Research(C) , Towards a real implementation of quantum network systems (2024-2026) , Principal Investigator

2. Akitada Sakurai: The Japan Society for the Promotion of Science (JSPS), Grant-in-Aid for Young Scientists, 量子機械学習における自然量子系による情報処理とその優位性の発現メカニズムの解明 (2025-2027) , Principal Investigator